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ORIGINAL ARTICLE

Favourable Anatomy After End-to-Side Repair of Interrupted Aortic Arch

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Objective To evaluate cardiovascular outcomes in patients with aortic arch repair and their possible correlation with arch geometry.

Methods Ten patients who underwent end-to-side repair for aortic arch interruption (IAA), older than 10 years were compared to a cohort of 10 post coarctation (CoA) repair patients matched for age, sex and age at repair. Mean age at operation was 9.7 ± 6.5 days. Patients underwent a resting and 24 h blood pressure measurements, exercise study, MRI, transthoracic echocardiography and vascular studies.

Results Seven patients developed hypertension, two from IAA group and five from CoA group. Nine patients (45%) had gothic arch geometry, three from IAA group and six from CoA group. Despite differences in arch geometry, both groups had normal LV mass, LV function and vascular function.

Conclusion No differences in functional or morphologic outcomes could be demonstrated between the end-to-side repair of the arch by sternotomy and the conventional coarctation repair by thoracotomy. A favourable arch geometry can be achieved after the end-to-side repair of the aortic arch. In the present study, we could not correlate adverse arch geometry with any adverse cardio-vascular outcomes. After neonatal arch repair, the contributive role of aortic arch geometry to late hypertension remains uncertain.

Keywords Aortic coarctation • Interrupted aortic arch • Hypertension • Aortic arch • Congenital heart disease • Comparative studies

Introduction

Hypertension is a known complication of coarctation repair [1–4]. The development of hypertension so early in life is related to a significant risk of premature death and cardiovascular co-morbidities [3,5,6]. The most important risk factor leading to hypertension is likely to be the presence of residual or recurrent arch obstruction [7,8]. We have demonstrated that the proximal transverse arch grows unreliably after coarctation performed by thoracotomy and suggested that more extensive operations performed by sternotomy should be contemplated if the proximal transverse arch is hypoplastic [9]. We have promoted the technique of end-to-side anastomosis for the relief of interrupted aortic arch and

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transverse arch hypoplasia, and demonstrated that this technique is associated with a low risk of late hypertension [9–12]. However, it has been advanced that end-organ damages may occur even in the absence of arch obstruction if the resulting geometry of the arch after repair is unfavourable [13]. We decided to investigate the arch geometry resulting from the end-to-side repair performed via sternotomy, and its relation to end-organ damages, and compare them to those operated by the conventional technique of aortic arch repair performed by thoracotomy.

Patients and Methods

Patients

The design of the study was approved by the local Hospital Ethics committee. The design of the study was a comparative investigation of patients operated by an end-to-side anastomosis for an interrupted aortic arch and a group of patients operated for coarctation repair matched for gender, age at operation and year of the procedure. Exclusion criteria were presence of clinical or Doppler flow evidence of structural restenosis of the aorta (an arm-leg blood pressure gradient > 20 mmHg or echocardiographic gradient above 25 mmHg across the repair), univentricular physiology, intellectual disability, and living outside Victoria.

Between January 1985 and December 1998, 80 patients underwent a repair of interrupted aortic arch at the Royal Children's Hospital in Melbourne, Australia. Sixty-eight patients were alive at the time of the study and 34 were living in Victoria. Of those, five were excluded because they had undergone a repair technique different than the end-to-side anastomosis, nine were excluded due to the presence of associated cardiac conditions seen as potential confounding factors, and three were excluded due to intellectual impairment and inability to follow instruction. Ten out of the 17 potential candidates (60%) were recruited for the study. A second matched cohort of 10 coarctation patients was recruited. These 20 patients constituted the study group. Written consent was obtained from all patients or their parents. The patients underwent the following examinations on the same day in our institution: resting blood pressure (BP) measurements, exercise study, transthoracic echocardiography, an MRI and a vascular study. At the end of the day the patients were fitted with a 24 h blood pressure monitoring device.

BP Measurements, Rest and Exercise

Resting BP in both arms and the left thigh were measured using the automatic oscillometric method (Dinamap® PRO 100; GE Healthcare, UK) after 5 min of rest in the supine position with appropriate sized cuffs. In adult subjects, blood pressure was considered elevated if the systolic pressure was greater or equal to 140 mmHg or the diastolic pressure was greater or equal to 90 mmHg, or if, in patients less than 18 years of age, pressures were above the 95th percentile for age [13]. The BP measurements were also converted to Z-scores adjusted for age using a separate reference population [14–16].

Treadmill exercise test was performed according to the Bruce protocol. Subjects were encouraged to exercise until reaching 90% of an age-specific maximum heart rate or until exhaustion. After the exercise had been stopped, subjects were asked to lie down immediately on the examination bed. BP was measured using the same automatic oscillometric method in the right upper arm and left thigh. This value was used to imitate maximum BP during exercise. Systolic hypertension at exercise was defined in children as maximum systolic BP at the 95th or greater percentile for a separate reference population [17] or 210 mm Hg or greater in men and 190 mm Hg or greater in women [18]. Exercise capacity and maximum heart rate were also assessed using age-adjusted reference values [19].

Transthoracic Echocardiography

Echocardiographic examinations were performed using a standard ultrasound machine (Vivid 7, GE Healthcare, UK). With patients in left lateral decubitus position. The protocol included imaging of standard planes: subcostal and apical four-chamber. Two-dimensional imaging, PLAX M-mode, pulse wave flow Doppler, as well as pulse wave tissue Doppler and colour tissue Doppler were performed. LV dimensions and tissue Doppler velocities were standardised to Z-score using a separate reference population at our institution [20].

Vascular Studies

Carotid and brachial artery ultrasound studies were performed using ultrasound mainframes (Vivid i, GE Healthcare, UK). A baseline brachial blood pressure was obtained just prior to the vascular studies after a period of 20 min of sitting quietly. Carotid measurements were taken by magnified imaging of the posterior wall of the right carotid artery approximately 10 mm from the border of the Bulbus to derive mean, maximum and minimum carotid intima-media thickness (IMT). Cross sectional area of intima-media layer were calculated because this parameter has been shown to be predictive of cardiovascular risk and left ventricular hypertrophy [21,22]. It was calculated using formula $\pi * [(\text{IMT} + \text{baseline diameter}/2)^2 - (\text{baseline diameter}/2)^2]$. The following indices of arterial elasticity were calculated: carotid compliance = [(Ds − Dd)/Dd]/(Ps − Pd); Young's elastic modulus = [(Ps − Pd) * Dd]/[(Ds − Dd)/IMT] and stiffness index = ln(Ps/Pd)/[(Ds − Dd)/Dd], where Dd is the diastolic diameter; Ds, the systolic diameter; Ps, systolic blood pressure; and Pd, diastolic blood pressure [23].

Brachial artery study investigated brachial flow mediated dilatation: the right brachial artery diameter was imaged 5–15 cm above the antecubital fossa. Vessel images were recorded at rest and during reactive hyperaemia. Increased arterial blood flow was induced by inflation of a blood pressure cuff placed on the forearm of the subject to 250 mmHg for 4.5 min before release. Several measurements of the brachial diameter were recorded over a 5 min period; at baseline, pre and post cuff release and at 40, 60, 80, 120, 180, 240 and 300 s intervals. The diameter of the brachial artery